

Pycnocline Distribution

Effects and consequences of the pycnocline on oxygen levels are not uniform in Chesapeake Bay and its tidal tributaries, however. Local characteristics, such as bathymetry and proximity to the ocean and where freshwater rivers enter the tidal waters, are critical. Assuming relatively predictable differences in freshwater flow, the pycnocline generally forms at similar depths, within several meters, every year. The pycnocline is generally deeper at the heads of tidal rivers and the mainstem Bay and shallower at the tidal river and Chesapeake Bay mouths. Due to Coriolis effects and prevailing winds, the pycnocline is typically deeper along the western shore than on the eastern shore. If a region is contained by both the pycnocline above and Bay bottom bathymetry laterally, as happens in the channels and deep holes, it is even more isolated from replenishing with water with higher oxygen concentrations. By contrast, the subpycnocline water-column layer closer to the mouth of Chesapeake Bay is continuously replenished with highly oxygenated bottom waters by ocean intrusion and, therefore, should show no natural low DO effects from being isolated from surface waters (Exhibit 4-12).

Following the protocol for calculating the presence of a pycnocline (Appendix D), areas of Chesapeake Bay's tidal waters were mapped where a pycnocline was present more than 50 percent of the time, based on analysis of spring and summer 1985–2000 tidal water quality data. Following detailed analyses of observed DO concentrations by depth over the 16-year data record of Chesapeake Bay water quality monitoring, areas were identified in which the presence of a pycnocline and the adjacent bottom bathymetry did and did not inhibit the continuous replenishment of subpycnocline waters with oxygenated waters.

Boundary Delineation Process

The first step in the process of delineating the boundaries of the designated uses was to decide how to divide the water column vertically into each respective designated use subcategory. Because the pycnocline is a naturally occurring physical boundary within the water column of Chesapeake Bay (and other estuarine systems) and because it has structure or thickness which can be defined with upper and lower depths, it was an obvious choice for dividing the uses. In those regions with all three refined designated uses, open-water would extend from the surface to the upper pycnocline depth, deep-water would occupy the volume between the upper and lower pycnocline depths and deep-channel would be the volume from the lower pycnocline depth to the bottom (**Exhibit 4-15**). In regions with a seasonally anoxic region (July and August only), that region would be defined as the volume between the bottom and half the distance between the bottom and the lower pycnocline depth.

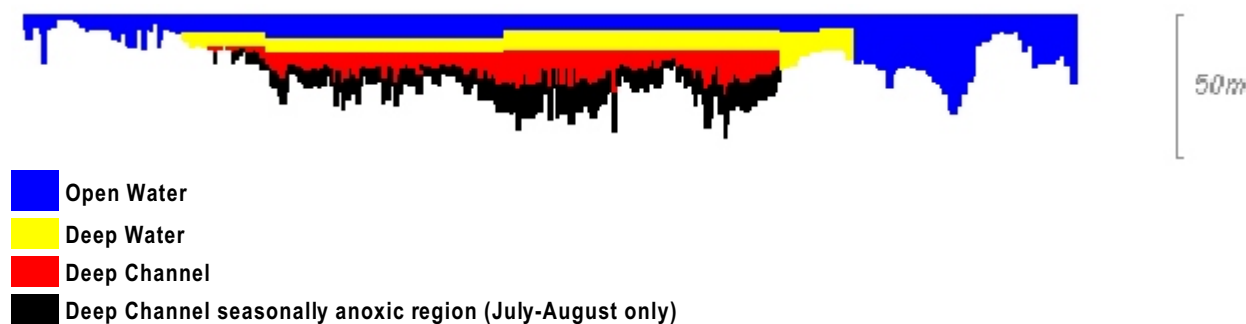


Exhibit 4-15: Profile of Vertical Distribution of the Open-water, Deep-water and Deep-channel Designated Use Subcategories in Mainstem Chesapeake Bay

The next step in the delineation process was to decide the horizontal extent of the designated uses—which regions of Chesapeake Bay should have open-water, deep-water and deep-channel uses, which should have just open-water and deep-water uses and which should have only the open-water use. Also, of those regions with a deep-channel seasonal refuge designated use, which of them should have a seasonally anoxic region. In delineating designated use boundaries, one of the key complexities of Chesapeake Bay hydrodynamics that must be factored in is that the presence of a pycnocline does not impact DO conditions to the same degree in all areas of Chesapeake Bay and its tidal tributaries.

Because those areas with a seasonally anoxic region would, by nature of the use definitions, also have all three designated uses, it was decided to delineate the seasonally anoxic regions of the tidal Chesapeake Bay waters and work outward from there. Based on the premise that the general location of the seasonal anoxic region is driven largely through natural physical features and hydrodynamic processes, but the relative size or extent is also the result of anthropogenic influences, results of analysis of the 17 year Chesapeake Bay water quality monitoring data record were used as a starting point. Finding the best summer DO conditions from the recent two decade record was the objective. The rationale was that areas that were severely hypoxic or anoxic in a year with the best (highest) DO conditions would be areas that are most directly impacted by natural hydrodynamic and bathymetric conditions and, therefore, reflective of the least anthropogenic impacts. Using hypoxic volume days as the metric for this assessment, 1997 was chosen as the year with the best summer DO conditions.

Mapping the bottom water DO for the summer of 1997 allowed the identification of those areas with chronically low DO which were therefore candidates for seasonally anoxic regions. Examining maps of the spatial extent of tidal waters with certain DO concentrations for the 1984 through 2000 period helped identify those areas where physical processes were impacting DO concentrations. Examining these maps year by year helped to identify those areas with persistent low DO problems where deep-water or deep-channel designated uses were necessary. Persistence of a low DO area over a period of 17 years with a wide range of flows and associated nutrient loads is indicative that the DO problem is not entirely anthropogenic. Generally, regions with persistent low DO are physically connected to the deep trench of the mainstem bay through natural or man-made channels. This connection allows for the advection of anoxic water from

the sub-pycnocline deep trench to the affected river (e.g., Chester River). Other regions may be in the opposite situation, where a bathymetric shoaling or sill at the mouth of the river causes isolation of the sub-pycnocline waters within the river (e.g., Rappahannock River).

In regions of the bay with deep-water and deep channel designated uses, the 1998–2000 May through September median segment pycnocline depths were used to delineate the designated use boundaries. Because these are segment median depths, boundary depths are uniform across the entire monitoring segment. In segments with seasonally anoxic regions, because the seasonally anoxic region is defined as half the distance from the bottom to the lower pycnocline depth, and because depth varies throughout a segment, the seasonally anoxic region boundary is the only boundary with a variable depth (Exhibit 4-15).

In the deep-channel designated use, seasonally anoxic regions are delineated where conditions of extremely low and no oxygen conditions persist naturally. Seasonally anoxic regions apply in the deep-channel designated uses of the mainstem Chesapeake Bay, Patapsco River, Chester River, Eastern Bay and Potomac River. These seasonally anoxic regions are applicable in July and August and occupy the volume between the bottom sediment-water interface and half distance between the bottom and the lower pycnocline depth.

Work is underway to set the actual vertical designated use boundaries on the observed pycnocline depth on a sampling event by event basis to use the most accurate use delineation for determining Bay criteria attainment.

Chesapeake Bay Mainstem Designated Use Boundaries

North of Back River, the open-water designated use extends to the bottom, even though the channel from this point north to Worton Point below Stillpond is stratified (Exhibit 4-12). These regions are shallow, predominantly freshwater to low salinity, and usually well-mixed. The region's proximity to the Susquehanna results in the replenishment of subpycnocline waters with oxygenated river waters in the absence of any bottom bathymetry barriers. Currently, in the bottom water of the southern portion of this channel, DO concentrations do occur in June through September at levels below the open-water DO criteria. Analysis indicates that there is an almost insignificant amount of non-attainment of the open-water DO criteria.

Below Back River in this region of the mainstem Bay, bottom waters show significantly higher salinity and more stratification than the water quality monitoring stations to the north. In spring and summer the higher salinity bottom water is likely to be oxygen-depleted water coming up from the trench. Due to physical processes, the lowest DO concentrations are typically found in bottom waters near the Chesapeake Bay Bridge near Annapolis, Maryland and these hypoxic waters are likely to spill over into the shallower waters north of the Bay Bridge. The up Bay extent of the deep-water designated use boundary starts off the mouth of Back River and follows the natural (and, in some sections, dredged) 30–40 foot/9–12 meter+ channel down Chesapeake Bay to beyond the mouth of the Rappahannock River (Exhibit 4-12).

The predominant down-Bay current flows along the western side, over a comparatively shallow area below the constriction at the Chesapeake Bay Bridge, near Annapolis, Maryland. Chesapeake Bay then broadens to an approximately 10-meter deep shelf running south to the mouth of the Patuxent River (the approximate end of Chesapeake Bay Program segment CB4MH). The deep channel runs alongside, closer to the eastern shore in this region, but then the channel curves and continues south to the Rappahannock River closer to the western shore. Shoal areas rise up from the bottom to form sills that separate the mainstem channel from the channels in the lower Patuxent and Potomac rivers.

As the natural channel reaches the **Chesapeake Bay Bridge** between Annapolis and Kent Island, the channel drops rapidly in depth, from 40–50 feet (12–15 meters) to 70–90 feet (21–27 meters). Once the water column reaches these deeper depths, a second pycnocline forms. It is the combination of the second pycnocline and the well-defined, yet confined channel that physically isolates the waters during the summer. The waters within the deep-channel designated use are blocked from surface reaeration due to the water column depth, vertical exchange with overlying waters due to presence of two pycnoclines above, and horizontal exchange with up or down Bay bottom waters due to the depth and walls of the channel itself. The deep channel use boundary follows this 60 foot/18 meter+ channel all the way down the mainstem to off the **mouth of the Rappahannock River** (Exhibit 4-12).

In the mainstem Chesapeake Bay, **between the mouths of the Potomac and Rappahannock rivers**, the Bay bottom rises from the midchannel deep trench (at 90 feet, or 27 meters) to shallower depths of less than 40 feet, or 12 meters. This shoal creates a hydrologic control point between the upper and lower mainstem Chesapeake Bay that regulates the exchange of deep waters of the trench to the north with deep waters of the southern trough that emerges in Pocomoke Sound and extends along the Virginia eastern shore to the Chesapeake Bay mouth. Below the region from the Potomac to Rappahannock rivers, the oceanic waters increasingly influence Chesapeake Bay water quality. Above this region, waters from the Susquehanna, Potomac and other rivers have a greater influence on Chesapeake Bay water quality conditions. Similarly, the sill at the mouth of the Potomac River and sills at the mouths of other tidal tributaries also regulate the exchange of water between the mainstem Bay and tidal rivers.

The effect of the hydrologic control point on the lower middle Bay can be seen in the different vertical structures of the monitoring stations in this area. Lower western shore monitoring stations CB5.4W, LE2.2, LE3.7, LE3.6 and CB6.1 through CB6.4 are all relatively shallow (less than 13 meters). These stations lie on the sill shelf that extends down the central and western areas of the lower Bay. They have an upper pycnocline in spring 60 to 70 percent of the time, more frequently in summer. The upper pycnocline in Chesapeake Bay Program segment CB6PH is deeper than 50 percent of the water column, which translates to an open-water designated use covering more than 50 percent of the water column, compared to CB5MH, whose extent of the water column above the pycnocline represents only one-fifth to one-third of the total water column. The lower pycnocline in Chesapeake Bay Program segment CB5MH is generally deeper even than the greatest depth of the CB6PH stations. A lower pycnocline is present less often in CB6PH and, when present, is very close to the upper pycnocline.

Median bottom salinity in the segment CB5MH deep-channel stations is only little lower than that in CB6PH stations, but surface salinities are higher in the CB6PH stations. The difference between surface and bottom salinity is less in segment CB6PH than in segment CB5MH, setting up for a weaker pycnocline and thus a less stable vertical barrier to mixing of oxygenated surface waters with oxygen reduced bottom waters. The salinity differential between segment CB6PH and the more marine water of segments CB7PH and CB8PH derives from contributions of both upstream Bay water and discharges of Virginia western shore rivers.

At the **mouth of the Rappahannock River**, the mainstem channel ends, shallowing quickly and becoming part of a larger shoal water area, which encompasses the islands separating Chesapeake Bay and Tangier Sound and continues diagonally across the Bay to Virginia's western shore below the Rappahannock River (approximately described by the southern border of Chesapeake Bay Program segment CB5MH) and continues down the western shore and central lower Bay (approximately the area of Chesapeake Bay Program segment CB6PH). The deep water designated use boundary in the mainstem Bay extends down Bay beyond the mouth of the Rappahannock River, following the gently upward sloping shoal waters to approximately the 40 foot/12 meter depth contour (Exhibit 4-12).

Examining year by year maps of interpolated July-August water quality monitoring data where the mean DO concentrations were less than 3 mg liter⁻¹ helped to identify those areas with persistent low DO problems in the mainstem Chesapeake Bay. Persistence of a low DO area over a period of years with a wide range of flows and associated nutrient loads is indicative that the DO problem is not entirely anthropogenic in origin. **Exhibit 4-16** focuses in on the section of the mainstem Chesapeake Bay between the Potomac and Rappahannock rivers. The pycnocline and bottom bathymetry based delineation of the deep-water boundary in this region of the Bay mainstem conforms well to the 17-year record of the bottom DO conditions (Exhibit 4-12). There are years when DO conditions less than 3 mg liter⁻¹ extend well beyond the proposed deep-water boundaries and years where such conditions don't fill in the boundaries.

The mainstem Chesapeake Bay deep trench ends at the boundary between monitoring segments CB5MH and CB6PH. A shallower trench then extends from the northern part of segment CB7PH to the Bay mouth. This combination of bathymetry and proximity to the Chesapeake Bay mouth lessens the impact of the pycnocline in this region of Chesapeake Bay and most of Chesapeake Bay Program segments CB6PH and CB7PH can support an open water designated use from the surface through the pycnocline to the bottom. The monitoring data indicate that low DO water from the deep trench in segment CB5MH may spill over the shoal or through the shipping channel between segments CB5MH and CB6PH. It appears that this occurs regularly which would indicate that a deep-water designated use is needed in this region. Exhibit 4-16 shows the area where the mean July and August bottom water DO was < 3 mg liter⁻¹.

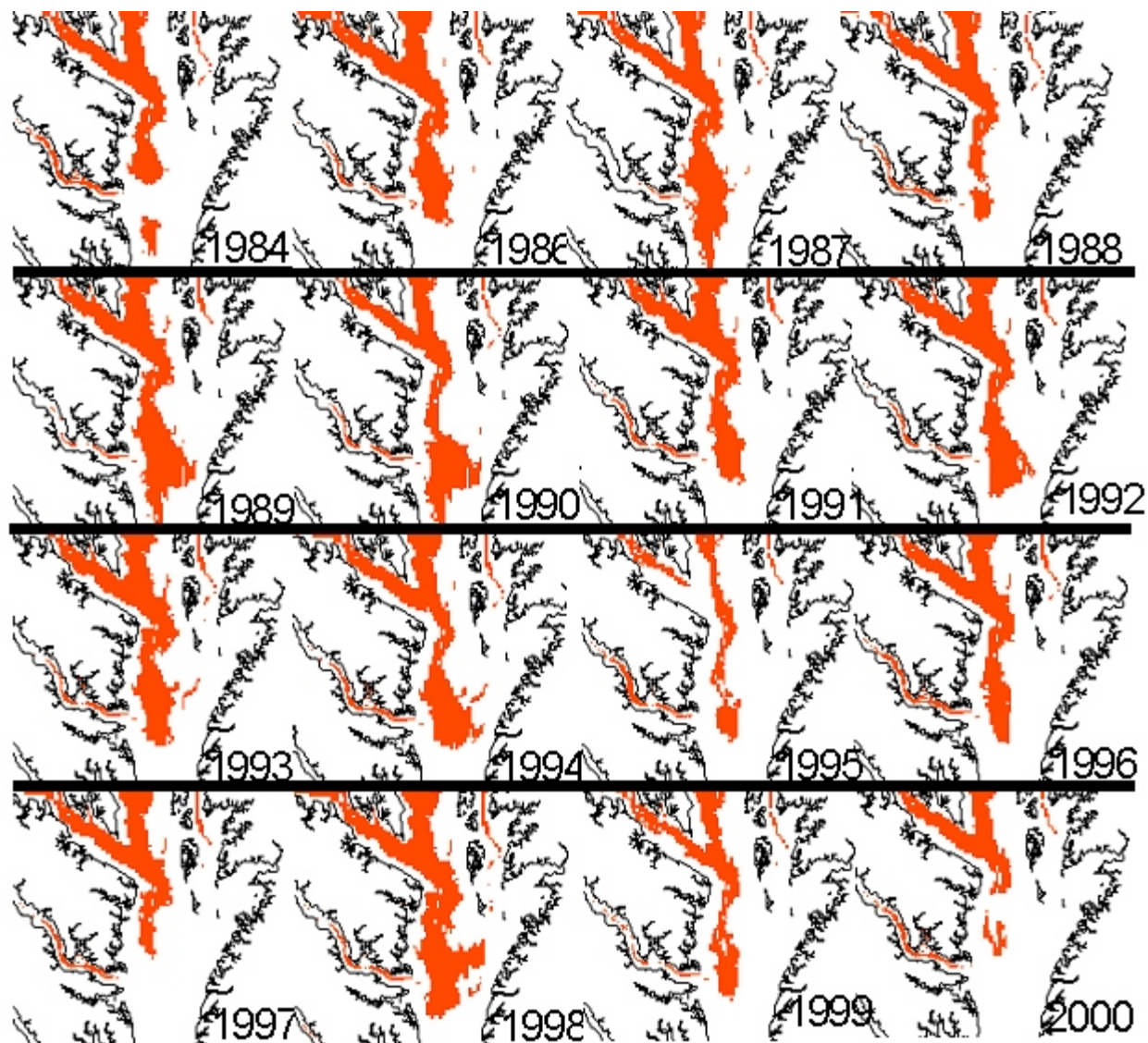


Exhibit 4-16: Areas in Chesapeake Bay Mainstem between the Potomac and Rappahannock River where July and August Mean DO Concentrations are $< 3 \text{ mg liter}^{-1}$: 1984–2000

Based on these maps the deep water designated use boundary shown in Exhibit 4-12 were developed. **Exhibit 4-17** shows the location of monitoring stations in segments CB6PH and CB7PH that are outside the deep-water area of in both segments. Bottom water DO data for the 1984-2001 summer period was analyzed to determine the percent occurrence of $\text{DO} < 3 \text{ mg liter}^{-1}$. The results are summarized for the 1984–1994, 1995–2001 and 1984–2001 periods in **Exhibit 4-18** and they indicate that although DO concentrations less than 3 mg liter^{-1} does occur, it does not happen often enough to suggest there is a physical hydrodynamic reason for adjusting the deep water boundaries.

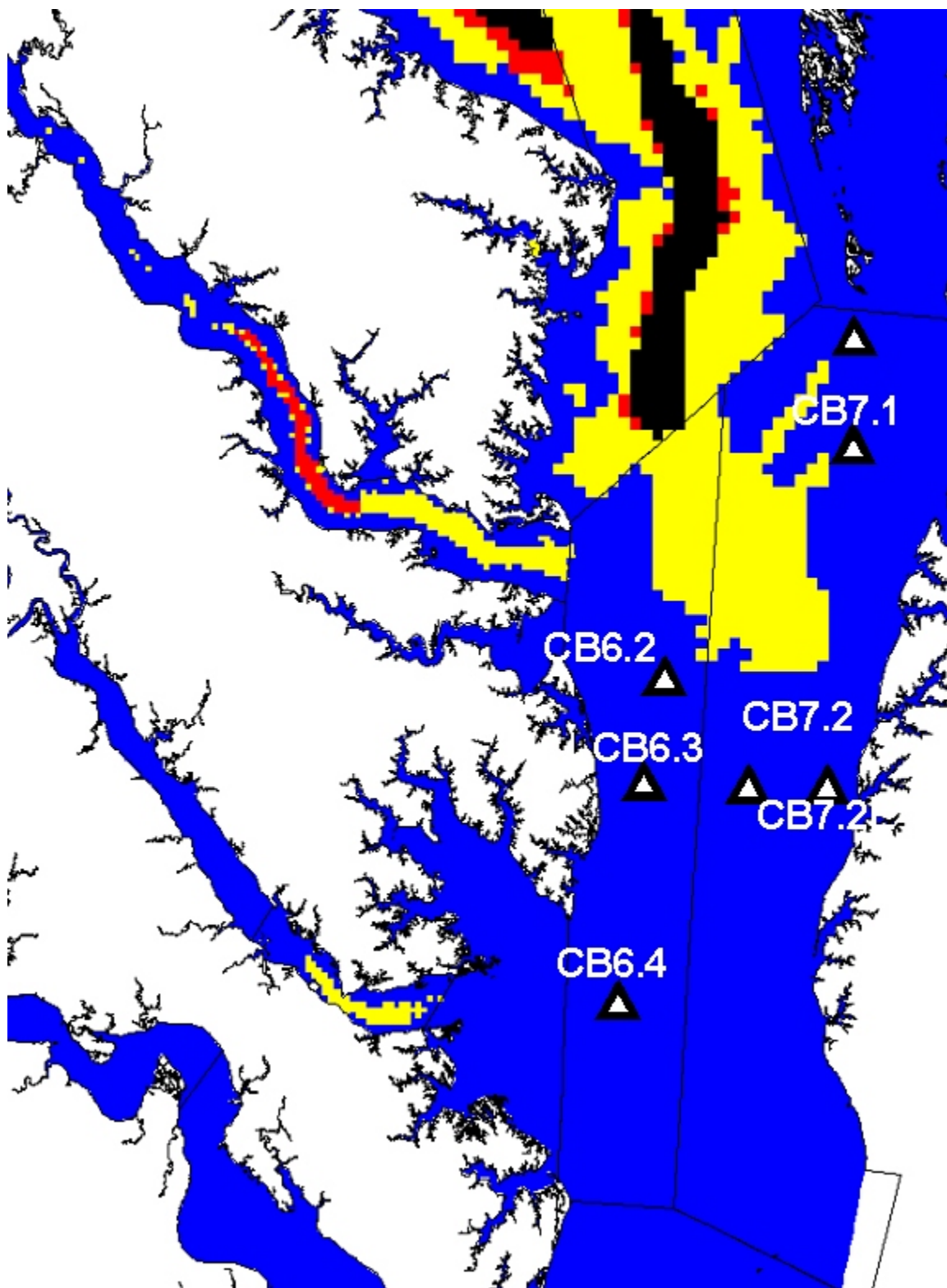


Exhibit 4-17: Current Designated Use Boundaries in the Southern Chesapeake Bay Mainstem are Illustrated Along with the Chesapeake Bay Water Quality Monitoring Program Stations Outside of the Deep-Water Designated Use in Segments CB6PH and CB7PH

Exhibit 4-18: Percent occurrence of summer bottom water DO concentrations < 3 mg liter⁻¹ at Chesapeake Bay water quality monitoring stations surrounding deep-water designated use in segments CB6PH and CB7PH

CBP Segment	Station	1984–1994	1995–2001	1984–2001
CB6PH	CB6.2	37	26	33
CB6PH	CB6.3	20	10	17
CB6PH	CB6.4	15	13	14
CB7PH	CB7.1	33	30	32
CB7PH	CB7.1N	17	8	14
CB7PH	CB7.2	3	6	4
CB7PH	CB7.2E	6	2	5

Given the influence of the Coriolis effect, which causes clockwise circulation of major oceanic currents, bottom waters of riverine origin tend to “flow down” the western side of the lower mainstem Chesapeake Bay with bottom waters of oceanic origin “flowing” up the eastern side of the lower mainstem Chesapeake Bay. These predominant flow patterns significantly influence the open-water designated use boundaries. Along the western side of the lower Chesapeake Bay, the open-water designated use extends to the bottom south of Windmill Point on the north shore of the **mouth of the Rappahannock River**. In the central portion of the lower mainstem Chesapeake Bay, **south of Nassawadox Creek**, the open-water designated use extends through the pycnocline down to the Bay bottom. Along the eastern side of the lower Chesapeake Bay, the oxygen-rich oceanic waters mediate the effect of stratification on bottom DO conditions farther up into Chesapeake Bay compared to the waters along the western side. Therefore, the open-water designated use extends from the surface to the bottom from **Tangier Sound south to the Chesapeake Bay mouth** (Exhibit 4-12). Above both of these regions, reoxygenation of subpycnocline waters by oceanic waters is sufficiently reduced to the point where DO concentrations necessary to protect open-water organisms cannot be sustained from June through September.

In the **Patapsco River**, a combination water column stratification, narrow and deep dredged shipping channels and direct hydrologic connections with deep waters in the adjacent mainstem Chesapeake Bay leads to delineation of a deep-water designated use in all tidal waters within the upper and lower boundaries of the pycnocline (Exhibit 4-12). The deep-channel designated use is present in all tidal waters below the lower pycnocline depth to the bottom sediment-water interface. The port of Baltimore shipping channels connects these deeper waters of this urban industrial estuary with the deep trench of the mainstem Chesapeake Bay.

The deep-water designated use in the **Chester River** is present in the region extending from the river mouth to just down-river of Southeast Creek. The deeper waters of the Chester River are directly connected to the mainstem Chesapeake Bay through a channel averaging 30 feet/ 9 meters beyond the river mouth. Within the river, the channel deepens to depths of up to 50–60 feet (15–19 meters). Within this deep water column, the second pycnocline forms leading to

delineation of the deep-channel designated use extending upriver from the mouth to just downriver of Southeast Creek (Exhibit 4-12). Above Southeast Creek, the river narrows and the main river channel gets progressively shallower.

A channel, varying in depth from 40–60 feet (12–18 meters) extends off the adjacent mainstem Chesapeake Bay and well up into **Eastern Bay**. The deep-water and deep-channel designated use boundaries follow this natural channel around Tilghman Point and down towards the entrance to the Miles River (Exhibit 4-12). The deep and confining nature of the channel lead to isolation of the pycnocline and beyond pycnocline waters.

Analysis of the 1985–2000 Chesapeake Bay water quality monitoring data record support delineation of deep-water and deep-channel designated uses in the Chester River and Eastern Bay. Both show areas of chronically low DO conditions (**Exhibit 4-19**). These low DO conditions may be due to circulation within the rivers themselves or may be partly due to advection of low DO water from the adjacent mainstem Chesapeake Bay.

The deep-water designated use in the **Patuxent River** is present in all waters below the upper pycnocline to the bottom in the region extending from the mouth upriver to just north of Swanson Creek (Exhibit 4-12). These deeper waters of Patuxent River are directly connected to the adjacent mainstem Chesapeake Bay. However, a sill at the river mouth largely prevents low oxygen waters from the adjacent mainstem Bay from flowing into the Patuxent River.

The lower Patuxent River is home to one of the deepest holes in Chesapeake Bay. Located off of Point Patience, subpycnocline waters within this hole become oxygen depleted during the summer months. However, relative to other tidal rivers, the level of oxygen depletion is not severe. Therefore, all waters below the upper pycnocline in the lower Patuxent River have only a deep-water designated use.

In the **Potomac River**, the deep-water designated use is present in all waters within the upper and lower boundaries of the pycnocline in the region extending from the mouth upriver to upriver to just below the Wicomico River (Exhibit 4-12). These deeper waters of the Potomac River are directly connected to the deep waters of the adjacent mainstem Chesapeake Bay. However, a wide shoal area along the western shore of the mainstem Bay prevent any direct connection between the deep channel region of the Potomac River and the similar region in the mainstem Chesapeake Bay. The deep-channel designated use boundary extends from the Potomac River mouth to Ragged Point where the 60 foot+ (18 meter) channel rapidly rises to 30–40 foot (9–12 meter) shoal waters extending across most of the river.

Similar to the Potomac River, a wide shallow, shoal area along the western shore and mouth of the river prevents any direct connection between the upriver deep-water and deep-channel regions within the **Rappahannock River** with the mainstem Chesapeake Bay. In the case of the Rappahannock, the bathymetric sill at the mouth of the Rappahannock River is an impediment to the in-flow of oxygenated waters from the adjacent mainstem.

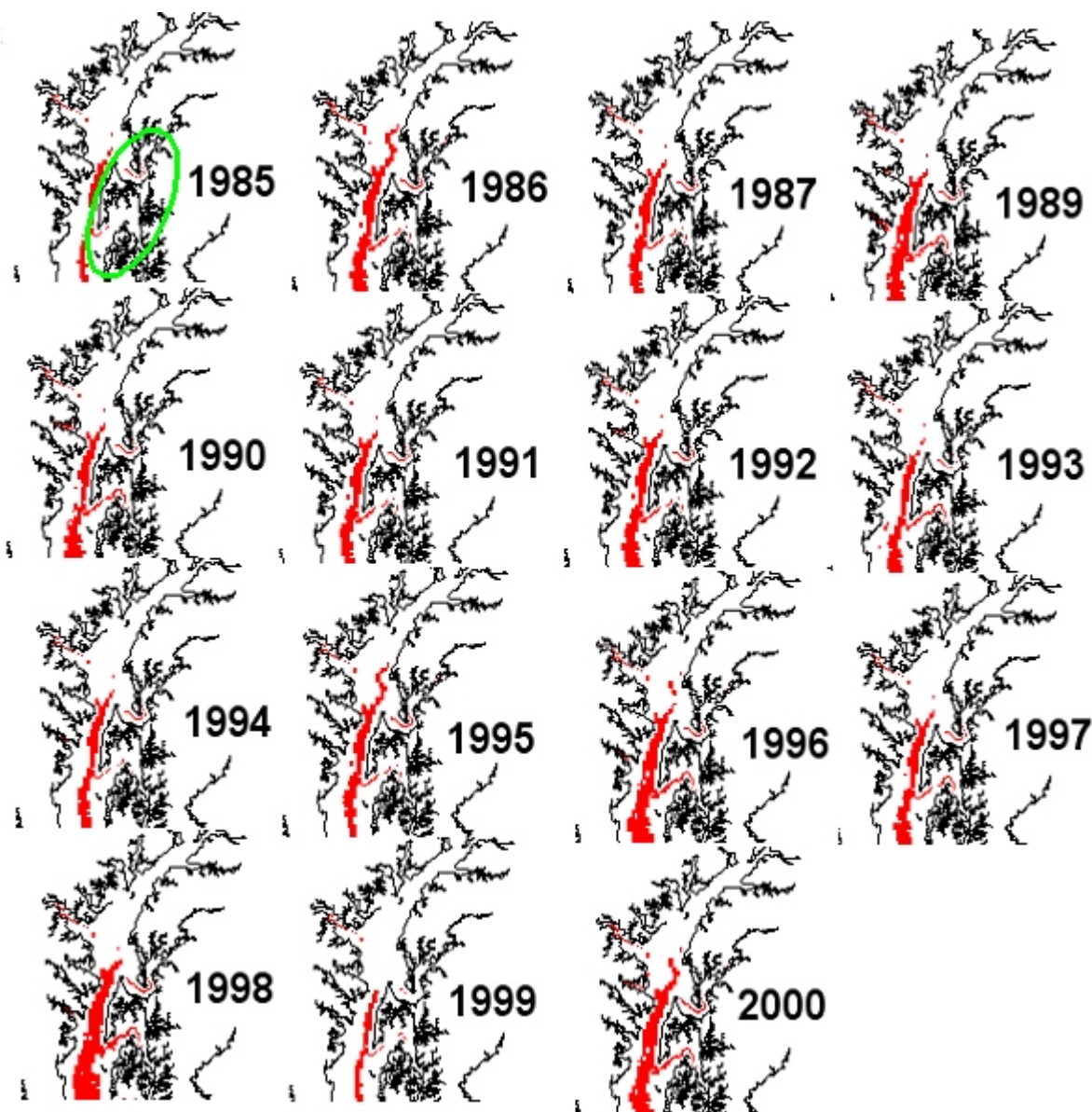


Exhibit 4-19: Areas in the Chester River and Eastern Bay where July and August mean DO concentrations are $< 3 \text{ mg liter}^{-1}$: 1985-2000.

Examination of the year by year maps of interpolated July-August water quality monitoring data where the mean DO concentrations were less than 1 mg liter^{-1} confirmed the pycnocline and bottom bathymetry based boundaries of the deep-channel designated use, located upriver of the Rappahannock River mouth (**Exhibit 4-20**). A combination of bathymetry and pycnocline results in isolation of the bottom waters in the lower Rappahannock River. Of particular interest is an area between Lancaster Creek and the Corrotoman River where these factors cause a persistent area of $\text{DO} < 1 \text{ mg liter}^{-1}$ (**Exhibit 4-20**) in the 1984 through 2000 time period. Given the persistence of low DO concentrations over a period of years with a wide range of flows and associated nutrient loads, this indicates that the low DO problem in this area is not entirely anthropogenic in origin.

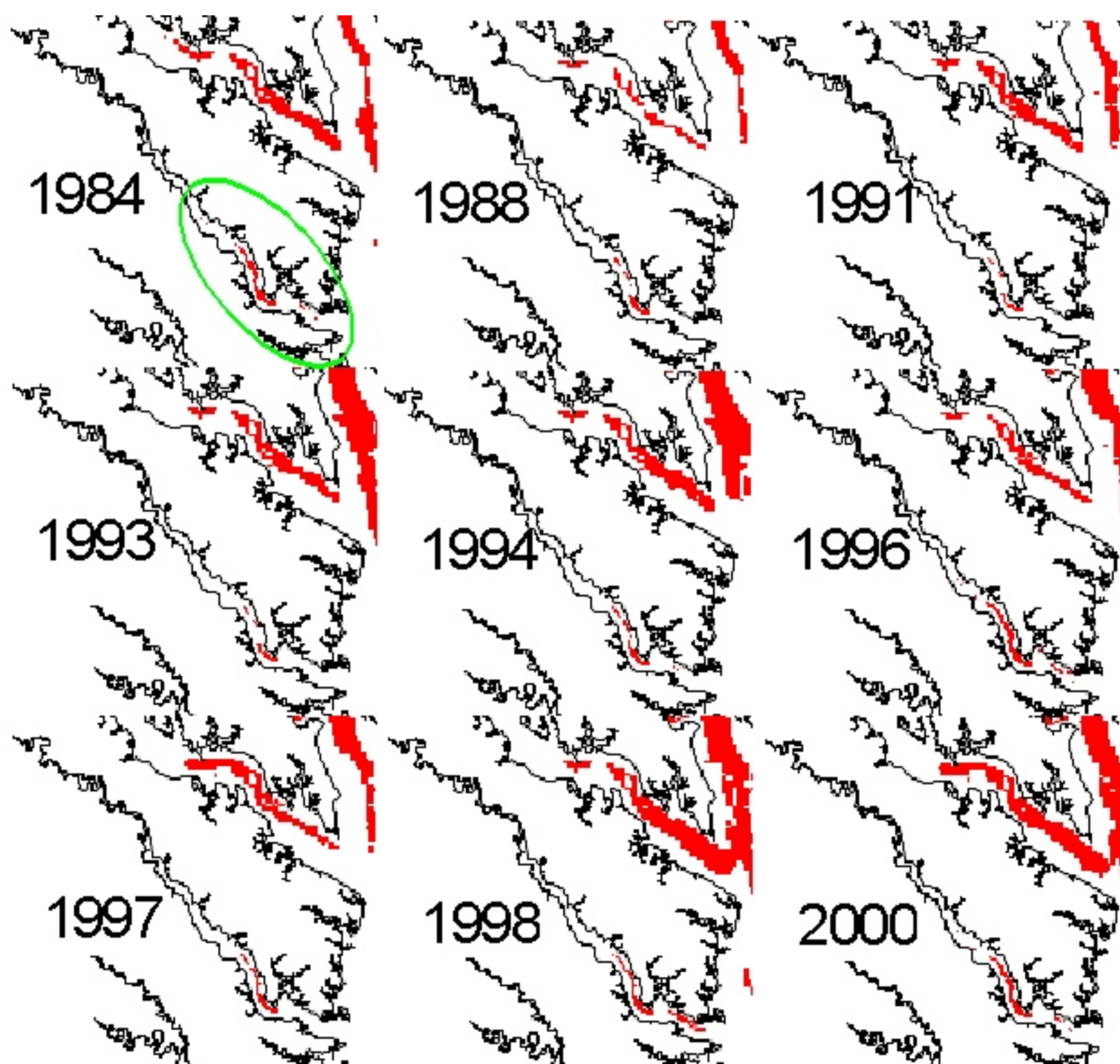


Exhibit 4-20: Areas in the Rappahannock River (circled) where July and August Mean DO Concentrations are $< 1 \text{ mg liter}^{-1}$: 1985–2000

The deep-water designated use in the Rappahannock River is present from the upper pycnocline depth to the bottom sediment-water interface in two regions: from the Rappahannock River mouth upriver to just past the Corrotoman River and from Lancaster Creek upriver to just past Carr Point Creek (Exhibit 4-12). In the region extending upriver from the Corrotoman River to Lancaster Creek, the deep-water designated use is present within the upper and lower boundaries of the pycnocline with the deep-channel use present in all tidal waters below the lower pycnocline depth to the bottom sediment-water interface in this same region (Exhibit 4-12).

The pycnocline impacts bottom water DO in the lower **York River** in the area delineated as deep-water designated use upriver from the mouth to Timberneck Creek. This region appears in **Exhibit 4-21** which shows the area of mean July-August bottom DO concentrations < 3 mg liter⁻¹ over a 17 year period. Bottom water DO data for the 1984–2001 summer period from stations surrounding this region (**Exhibit 4-22**) were analyzed to determine the percent of observations where DO concentrations was < 3 mg liter⁻¹. The results are summarized for the 1984–1994, 1995–2001 and 1984–2001 periods in **Exhibit 4-23** and they indicate that although DO concentration less than 3 mg liter⁻¹ do occur, it does not happen often enough to suggest there is a physical hydrodynamic reason for adjusting the deep water boundaries as from what is shown in Exhibit 4-12.

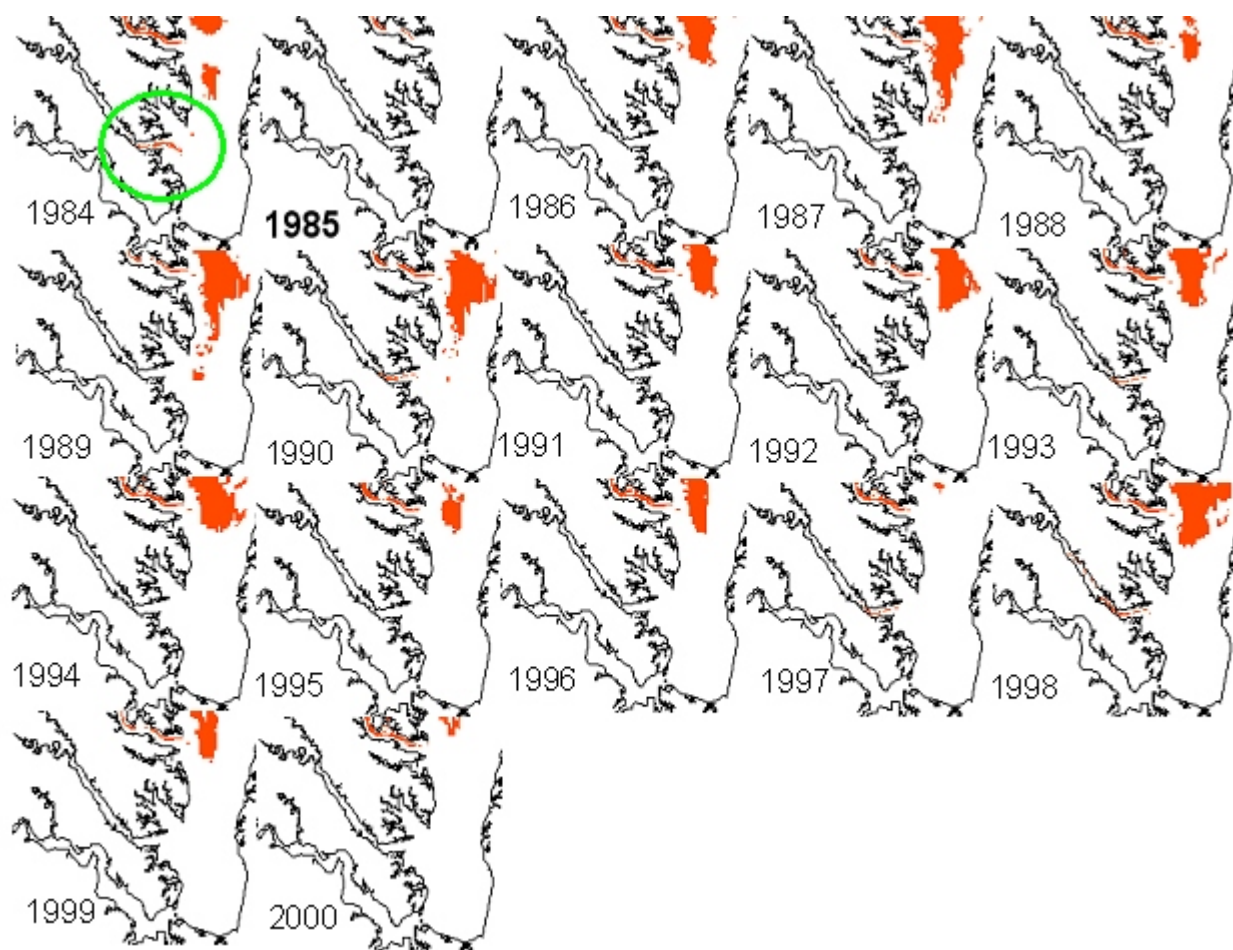


Exhibit 4-21: Areas in the York River (circled) where July and August Mean DO Concentrations are < 3 mg liter⁻¹: 1985–2000

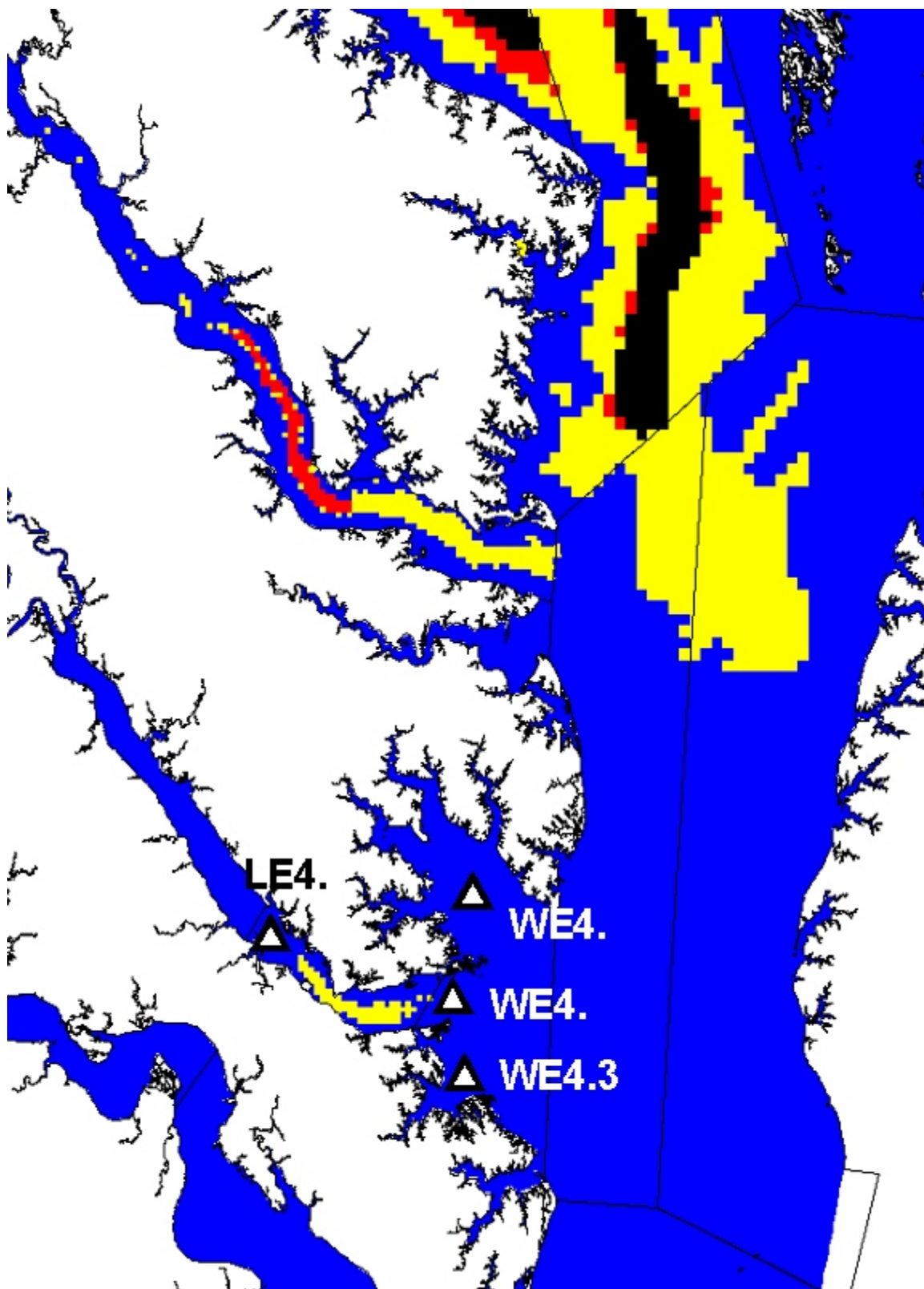


Exhibit 4-22: Proposed Subcategory Designated Use Boundaries in the York River—Chesapeake Bay Water Quality Monitoring Program Stations Outside of the Deep-Water Designated Use

Exhibit 4-23: Percent Occurrence of Summer Bottom Water DO Concentrations < 3 mg liter⁻¹ at Chesapeake Bay Water Quality Monitoring Program Stations Surrounding the Deep-Water Designated Use in the Lower York River.

CBP Segment	Station	1984–1994	1995–2001	1984–2001
MOBPH	WE4.1	4	0	3
MOBPH	WE4.2	38	19	31
MOBPH	WE4.3	5	2	4
YRKPH	LE4.2	14	12	13

4.3.2 Shallow-Water Designated Use Boundaries

The 2-meter depth contour was selected as the maximum depth for the lower vertical boundary for the shallow-water designated use. This is the maximum depth to which underwater bay grasses could be restored in many of the tidal tributaries and mainstem Chesapeake Bay shallow-water habitats. Although historical bay grass beds in the Chesapeake Bay probably grew to 3 meters or more, the 2-meter depth was chosen following an extensive evaluation of grass bed distribution over the past 30 years and of light levels anticipated to be required to restore viable shallow water habitats out to the 2-meter depth (Batiuk et al., 1992; Dennison et al., 1993; Moore et al., 1999; Batiuk et al., 2000; Moore et al., 2001; Naylor, 2002).

The intertidal zone was selected as the inner boundary for the shallow-water bay grass designated use, as some species of bay grass can grow in the upper end of the intertidal zone (Batiuk et al., 2000; Koch, 2001). Numerous field studies of bay grasses distributions in the Chesapeake Bay and its tidal tributaries have indicated that what is controlling the minimum depth of bay grasses distribution is not wave action or other factors, but length of exposure to air at low tide (Moore, unpublished data; Naylor, unpublished data).

Shallow water habitats may also be offshore flats such as observed in Tangier Sound and Poquoson Flats in the lower mainstem Chesapeake Bay. These areas may have an inner boundary not in the intertidal zone but rather a relatively deep/wide channel between them and the shore. These areas are included in the delineation of shallow-water bay grass designated use habitats if they currently have or historically had bay grasses and met the decision rules described below.

Benefits of Deeper Bay Grasses Distributions

There are obvious benefits to restoring underwater bay grasses to the greater depths where they previously existed in Chesapeake Bay (**Exhibit 4-24**). Increasing the depth and, therefore, the areal distribution of bay grasses can greatly increase the habitat and food available to the Bay's fish, crabs and waterfowl that depend on it.

Exhibit 4-24: Ecological benefits of restoring underwater bay grass beds to deeper depths

- Ensures growth of bay grasses where there may have previously been none because of wave energy at shallower depths prevented plants from rooting into the bottom sediments (e.g., the beds that formerly grew on the western side of Kent Island, Maryland at depths greater than where the critical wave energy threshold exists);
 - Adds habitat below the grazing depth of mute swans and non-migratory Canada geese (approximately 1 and 0.5 meters, respectively) to increase food availability for native waterfowl;
 - Reduces the likelihood of ice damage to bay grass beds;
 - Reduces the negative effects of unusually low tides;
 - Minimizes thermal stress (as deeper bay grass beds are inherently cooler);
 - Stabilizes sediments at greater depths (through the reduction of water velocity within the bay grass beds);
- Increases overall nutrient uptake and support increased denitrification;
- Increases summer-time oxygen production (which is particularly important in the headwaters of tidal creeks); and
 - Increases habitat for fish, crabs and macroinvertebrates.

It is important to note that bay grasses distribution is directly related to the bathymetry of the basins in which it occurs. In a shallow bay with gradual slope to deeper waters, like the Chesapeake Bay, even a moderate increase in water clarity can result in tremendous increases in the aerial extent of bay grasses.

Historical Bay Grass Distributions

The distribution and, therefore, the depth of historical bay grass beds were mapped from photographs dating from the late 1930s through mid-1960s by scientists at the Maryland Department of Natural Resources and the Virginia Institute of Marine Science. Historical bay grasses distribution data from Maryland and Virginia were aggregated into a single data set using ArcInfo GIS software. Approaches were taken by the two States that reflect differences in the quality and quantity of historical aerial photographs available for interpretation. Full documentation on the methods employed and the detailed results are reported by Moore et al., 1999, 2001 and Naylor et al., 2002.

To determine historic bay grass acreage, aerial photos from 1938, 1952, 1957 and 1964 were evaluated visually for Maryland's portion of the Chesapeake Bay to determine the year with the most bay grass visible for each area (Naylor, 2002). The photos for the year of greatest abundance in each area were then scanned, geo-referenced and photo-interpreted to determine the extent of bay grass beds from these years.

In the Virginia portion of Chesapeake Bay and its tidal tributaries, historical bay grass acreage in the James River was mapped from individual years of available photography—1937, 1947, 1948, 1953, 1954, 1958, 1959, 1963, 1968, 1969, 1970 and 1973—with the historical coverage defined by the composite of the individual years (Moore et al., 1999). Historical and recent ground survey results were overlaid on the composite maps of historical bay grass distributions to help determine whether the patterns exhibited on the historical photography were actually those of bay grass beds (Moore et al., 1999).

For the Rappahannock and York rivers and the adjacent smaller western shore rivers, creeks and embayments, a series of photographs from 1952 to 1956 were chosen to delineate the maximum coverage of bay grasses in these areas (Moore et al., 2001). The photography available from 1936 and 1937 from these rivers showed less bay grasses coverage compared to the 1950s photography. The difference appeared to be related to overall poorer atmospheric and water clarity conditions at the time the photographs were taken, making the bay grass beds less apparent in the 1930s photographs (Moore et al., 2001).

The photo interpretation of historic aerial photographs from both States followed as closely as possible the methods currently used to delineate bay grass beds throughout the Chesapeake Bay and its tidal tributaries through annual aerial bay grass surveys (e.g., Orth et al., 2000). In the case of both States, no single year of photography provided full coverage of complete areas of the respective States' entire tidal shoreline.

These State-specific analyses provide a conservative estimate of past bay grass distributions prior to the early 1970s. The older photographs were not collected specifically to map bay grasses; most of the imagery used for historical bay grass distribution mapping was obtained for other purposes, usually to analyze land use or farming practices. While the criteria for atmospheric conditions were usually met, the factors that are important for delineating and mapping bay grasses (e.g., tidal stage, water transparency and plant growth stage) often were not met. Bay grasses grew at greater depths between the 1930s and 1960s, according to published and anecdotal information, than was observed in a number of segments through interpretation of the historical photographs. As bay grasses grow deeper, beyond the 1-meter depth contour, they become increasingly difficult to map, given the conditions under which the historical photographs were collected. There were limited numbers of years—often only 3 to 5—for which historical photographs of a particular shallow-water habitat region were available for interpretation and mapping between the 1930s and 1960s. Evidence suggests that bay grasses distributions already had declined by the time photographs of suitable quality were available for interpretation (Moore et al., 1999). All of these factors led to conservative estimates of past bay grasses distributions and depths of bed growth.

Bay Grass No-Grow Zones

A series of bay grass “no-grow zones” were originally delineated in 1992. Habitats exposed to high wave energy or which have undergone physical modifications such that they could not support bay grasses growth were excluded based on an extensive review of data available at the time (Batiuk et al., 1992). With the mapping of historical bay grasses distributions, as described

above, a composite of available bay grass distribution data from the 1930s through 2000 was superimposed on the 1992 bay grass no-grow zones. A number of shoreline habitats previously considered no-grow zones showed clear evidence of historical bay grass growth and, therefore, their no-grow zone designation was dropped. These revised bay grass no-grow zones also include areas where the no-grow zone applies to a 1- to 2-meter depth contour as well as a 0- to 2-meter depth contour.

The revised bay grass no-grow zones illustrated in **Exhibit 4-25** (Appendix C) show shoreline habitats of 2 meters or less where Bay grasses are never expected to grow due to:

- Extreme physical wave energy preventing the plants from rooting into the bottom sediments (e.g., Calvert Cliffs on Maryland's lower western shore, Willoughby Split to Cape Henry near the Chesapeake Bay mouth in Virginia);
- Permanent physical alterations to nearshore habitats including dredging close to shore accompanied by hardening of the shoreline and installation of permanent structures (i.e., shipping terminals) as observed in the inner Baltimore Harbor and the Elizabeth River;
- Natural, extreme discoloration of the water from tidal-fresh wetlands (e.g., tidal fresh "blackwater" rivers on the Eastern Shore); or
- No functional shallow-water habitat due to natural river channeling (e.g., tidal headwaters of lower Eastern Shore rivers).

These bay grass no grow zones reflect the full set of findings on bay grasses distributions from the historical (1930s–early 1970s) and 1978–2000 data records as well as altered nearshore/ shoreline habitats as described above. If there are no physical reasons why bay grasses can not grow in a specific shallow-water habitat, it should be expected that bay grasses can grow there given appropriate water quality conditions and local sources of propagules.

Shallow-Water Bay Grass Designated Use Depth Boundaries

The established bay grass no-grow zones were removed at the beginning from the area identified as potential bay grass habitat by the different depth intervals (e.g., 0 to 0.5 meters, >0.5 to 1 meter and >1 to 2 meters) within each of the 78 Chesapeake Bay Program segments.

A set of decision rules were developed for defining the maximum depth of bay grass beds by Chesapeake Bay Program segment (see Exhibits 4-13 and 4-14).

These decision rules take full advantage of the entire record of bay grass distribution and abundance survey data. The decision rules were set up to ensure full consistency between the establishment of the shallow-water bay grass designated use depths (the depth at which the Chesapeake Bay water clarity criteria will be applied) and the basis for setting the new quantitative bay grasses acreage restoration goal for Chesapeake Bay and its tidal tributaries.

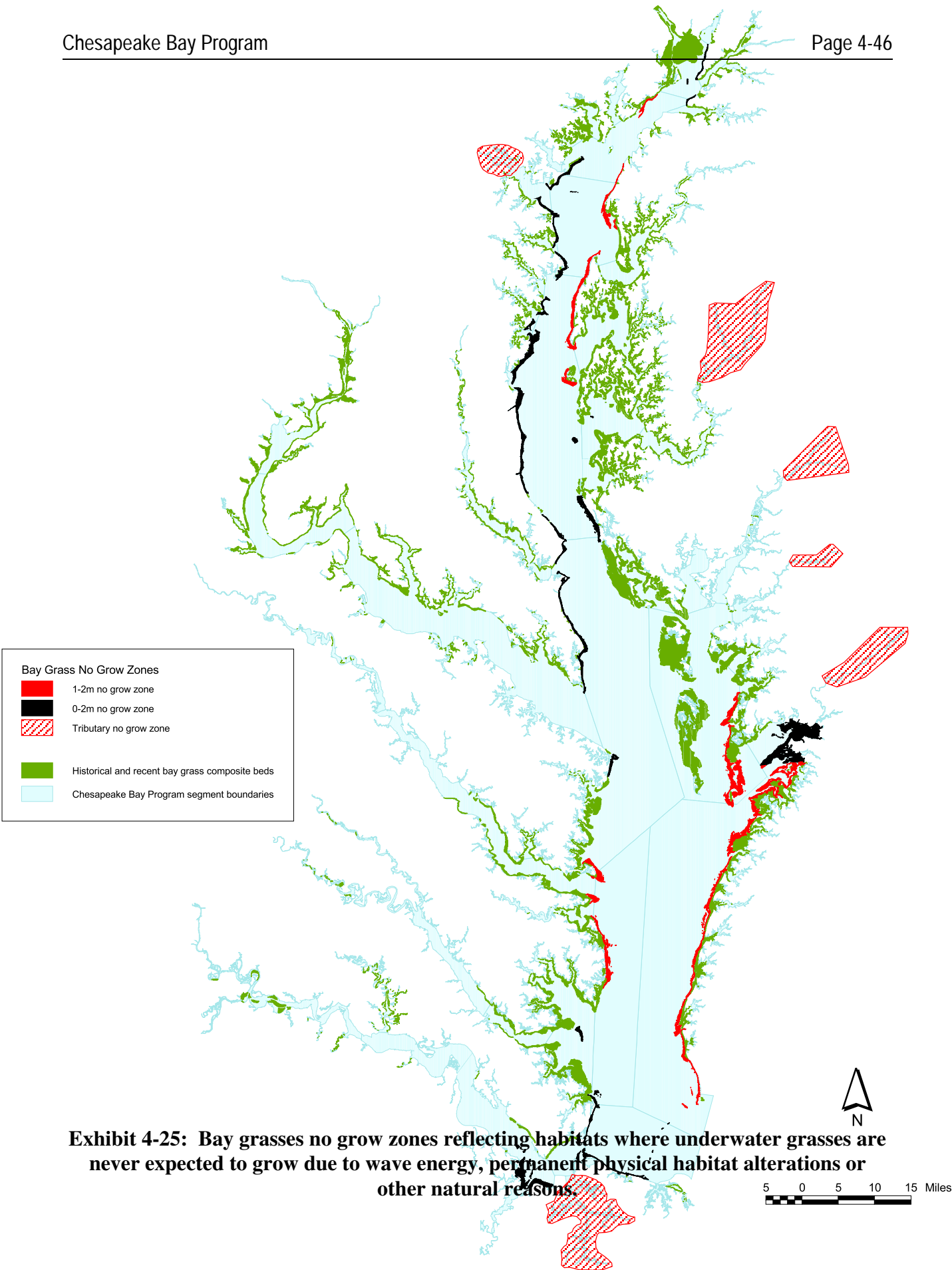


Exhibit 4-25: Bay grasses no grow zones reflecting habitats where underwater grasses are never expected to grow due to wave energy, permanent physical habitat alterations or other natural reasons.

The available data record included interpreted aerial photography from the 1930s to the early 1970s (i.e., “historical” data) as well as the annual bay-wide aerial survey data from 1978–2000. From these interpreted photos and surveys, the acreage of bay grasses within three depth intervals were calculated for every Chesapeake Bay Program segment (Appendix B). The depth intervals are 0–0.5 m, > 0.5–1 m and > 1–2 m and are to be interpreted as bounded by the higher depth. Thus, each Chesapeake Bay Program segment has three “segment-depth intervals” (e.g., CB4MH 1–2 m is a segment-depth interval).

The total surface area within each segment-depth interval, minus any delineated bay grass no grow zones, is an estimate of the area of potential bay grass habitat in that segment-depth interval. Thus, there is an acreage of potential habitat for each of the three segment-depth intervals in every Chesapeake Bay Program segment except for select segments where the bay grass no grow zones encompass the entire segment (**Exhibit 4-26**, Appendix C).

Exhibit 4-26: Basis for determining the shallow-water bay grasses designated-use boundary depths.


CBP Segment Name	CBP Segment	Single Best Year	Maximum Depth at which SAV Water Clarity Criteria Apply			Shallow Water Use Depth
			0–0.5 m	0.5–1 m	1–2 m	
Northern Chesapeake Bay	CB1TF	Historical				2
Upper Chesapeake Bay	CB2OH	Historical				0.5
Upper Central Chesapeake Bay	CB3MH	1978				0.5
Middle Central Chesapeake Bay	CB4MH	Historical				2
Lower Central Chesapeake Bay	CB5MH	Historical				2
Western Lower Chesapeake Bay	CB6PH	Historical				1
Eastern Lower Chesapeake Bay	CB7PH	1993				2
Mouth of the Chesapeake Bay	CB8PH	1996				0.5
Bush River	BSHOH	Historical				0.5
Gunpowder River	GUNOH	2000				2
Middle River	MIDOH	Historical				2
Back River	BACOH	*				0.5
Patapsco River	PATMH	Historical				1
Magothy River	MAGMH	Historical				1
Severn River	SEVMH	1999				1
South River	SOUMH	Historical				1
Rhode River	RHDMH	Historical				0.5
West River	WSTMH	Historical				0.5
Upper Patuxent River	PAXTF	1996				0.5
Western Branch (Patuxent River)	WBRTF	*				0.5
Middle Patuxent River	PAXOH	2000				0.5
Lower Patuxent River	PAXMH	Historical				2


Exhibit 4-26: Basis for determining the shallow-water bay grasses designated-use boundary depths.


CBP Segment Name	CBP Segment	Single Best Year	Maximum Depth at which SAV Water Clarity Criteria Apply			Shallow Water Use Depth
			0–0.5 m	0.5–1 m	1–2 m	
Upper Potomac River	POTTF	1991				2
Piscataway Creek	PISTF	1987				2
Mattawoman Creek	MATTF	2000				1
Middle Potomac River	POTOH	1998				2
Lower Potomac River	POTMH	Historical				1
Upper Rappahannock River	RPPTF	2000				0.5
Middle Rappahannock River	RPPHOH	*				0.5
Lower Rappahannock River	RPPMH	Historical				1
Corrotoman River	CRRMH	Historical				1
Piankatank River	PIAMH	Historical				2
Upper Mattaponi River	MPNTF	1998				0.5
Lower Mattaponi River	MPNOH	*				0.5
Upper Pamunkey River	PMKTF	1998				0.5
Lower Pamunkey River	PMKOH	*				0.5
Middle York River	YRKMH	Historical				0.5
Lower York River	YRKPH	Historical				1
Mobjack Bay	MOBPH	Historical				2
Upper James River	JMSTF	Historical				0.5
Appomattox River	APPTF	Historical				0.5
Middle James River	JMSOH	1998				0.5
Chickahominy River	CHKOH	2000				0.5
Lower James River	JMSMH	Historical				0.5
Mouth of the James River	JMSPH	Historical				1
Western Branch Elizabeth River	WBEMH	*				*
Southern Branch Elizabeth River	SBEMH	*				*
Eastern Branch Elizabeth River	EBEMH	*				*
Middle Elizabeth River	ELIMH	*				*
Lafayette River	LAFMH	*				*
Mouth of the Elizabeth River	ELIPH	*				*
Lynnhaven River	LYNPH	1986				0.5
Northeast River	NORTF	Historical				0.5
C&D Canal	C&DOH	1978				0.5
Bohemia River	BOHOH	2000				0.5
Elk River	ELKOH	2000				2


Exhibit 4-26: Basis for determining the shallow-water bay grasses designated-use boundary depths.

CBP Segment Name	CBP Segment	Single Best Year	Maximum Depth at which SAV Water Clarity Criteria Apply			Shallow Water Use Depth
			0–0.5 m	0.5–1 m	1–2 m	
Sassafras River	SASOH	2000				1
Upper Chester River	CHSTF	*				0.5
Middle Chester River	CHSOH	Historical				0.5
Lower Chester River	CHSMH	Historical				1
Eastern Bay	EASMH	Historical				2
Upper Choptank River	CHOTF	*				*
Middle Choptank River	CHOOH	Historical				0.5
Lower Choptank River	CHOMH2	Historical				1
Mouth of the Choptank River	CHOMH1	Historical				2
Little Choptank River	LCHMH	Historical				2
Honga River	HNGMH	Historical				2
Fishing Bay	FSBMH	Historical				0.5
Upper Nanticoke River	NANTF	*				*
Middle Nanticoke River	NANOH	Historical				0.5
Lower Nanticoke River	NANMH	Historical				0.5
Wicomico River	WICMH	Historical				0.5
Manokin River	MANMH	Historical				2
Big Annemessex River	BIGMH	Historical				2
Upper Pocomoke River	POCTF	*				*
Middle Pocomoke River	POCOH	*				0.5
Lower Pocomoke River	POCMH	1993				1
Tangier Sound	TANMH	Historical				2

 Decision rules not met – default depth of 0.5 meters applies.

 Single best year percent of total potential habitat is ≥ 20 percent.

 Percent of total potential habitat is 10–19.9% and bay grasses are persistent (1978–2000).

 Chesapeake Bay Program segment completely within the bay grass no-grow zone.

*Denotes no data available or no bay grasses mapped.

The set of decision rules which follow are based on the observed single best year of bay grass coverage for each whole Chesapeake Bay Program segment (i.e., not the single best year by segment-depth). Using each segment's single best year, the percentage of available habitat at each segment-depth interval that was occupied by bay grasses in that single best year was calculated (Appendix B, Exhibit B-2). That percentage is a measure of the relative importance of each segment-depth interval as bay grass habitat.

In order to provide an additional measure of the importance of a segment-depth interval as bay grass habitat, the record of bay grass aerial survey data from 1978–2000 (there is not a survey for every year between 1979–1983 and in 1988) was segmented into four five-survey intervals (**Exhibit 4-27**). The persistence of bay grasses in each segment-depth interval was then assessed by counting the number of five-survey intervals in which a meaningful percentage of potential habitat is occupied by bay grasses.

Exhibit 4-27: Percent of potential shallow-water habitat covered by underwater bay grasses from 1978–2000 at five-year intervals.

Bay Segment	1978–1984			1985–1990			1991–1995			1996–2000		
	0–0.5 m	0.5–1 m	1–2 m	0–0.5 m	0.5–1 m	1–2 m	0–0.5 m	0.5–1 m	1–2 m	0–0.5 m	0.5–1 m	1–2 m
CB1TF	51.0	26.3	14.9	61.1	29.8	17.3	66.0	30.0	9.5	80.1	36.8	9.4
NORTF	2.1	0.1	0.0	0.3	0.0	0.0	5.8	0.3	0.0	6.8	0.0	0.0
ELKOH	1.8	0.5	0.0	18.1	24.8	22.1	19.0	20.3	22.4	36.3	33.8	34.5
C&DOH	0.2	0.9	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BOHOH	0.0	0.0	0.0	4.0	1.8	0.0	4.0	0.1	0.0	14.6	8.0	6.1
BSHOH	0.2	0.0	0.0	2.8	1.4	0.0	0.4	0.0	0.0	11.4	9.4	1.2
CB2OH	4.6	1.2	0.2	7.9	8.5	1.8	2.3	1.9	0.2	13.2	8.1	6.2
GUNOH	15.9	8.9	4.2	8.6	6.9	3.4	12.7	7.4	3.4	54.1	40.1	30.0
SASOH	1.4	0.7	0.0	6.8	6.5	7.9	18.0	15.9	0.9	28.0	40.5	12.7
MIDOH	43.4	18.1	3.8	11.9	11.3	9.1	10.3	4.8	0.7	41.0	41.1	19.0
BACOH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PATMH	6.0	5.3	0.7	0.0	0.0	0.0	0.1	0.0	0.0	1.0	0.4	0.0
CHSTF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CHSOH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CB3MH	52.7	21.3	7.5	41.3	4.5	0.9	39.4	4.6	1.0	41.9	6.1	0.8
CHSMH	52.5	25.2	5.0	22.9	5.5	1.0	22.4	7.7	1.4	24.9	10.0	2.1
MAGMH	40.5	16.8	6.5	0.8	0.4	0.0	8.6	2.3	0.3	21.8	5.5	1.0
SEVMH	25.4	19.5	7.8	0.0	0.0	0.0	7.9	8.9	1.7	27.7	24.7	11.7
CB4MH	5.5	0.6	0.0	2.5	0.0	0.0	0.7	0.0	0.0	2.1	0.0	0.0
POTTF	5.2	18.0	3.3	31.6	67.6	23.9	38.3	62.1	16.1	35.0	53.1	11.0
CHOTF	*	*	*	*	*	*	*	*	*	*	*	*
SOUH	4.5	0.8	0.4	0.0	0.0	0.0	0.5	0.3	0.0	6.4	1.7	0.4
EASMH	33.2	13.8	2.5	37.5	11.7	1.6	38.4	11.9	1.5	54.8	28.3	3.9
RHDMH	4.6	0.7	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WSTMH	17.8	1.8	0.2	0.9	0.0	0.0	2.1	0.0	0.0	1.4	0.0	0.0
CHOMH1	43.4	20.4	6.2	44.4	14.8	2.1	46.8	25.4	5.2	64.8	38.9	8.4
CHOOH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PAXTF	0.0	0.0	0.0	0.0	0.0	0.0	23.1	15.4	9.6	39.5	22.6	15.3
WBRTF	*	*	*	*	*	*	*	*	*	*	*	*
PISTF	40.3	50.0	21.6	76.7	96.0	90.6	29.4	48.1	18.0	67.2	49.7	17.6
PAXOH	0.2	0.0	0.0	0.0	0.0	0.0	5.5	0.1	0.0	8.4	2.9	0.5
CHOMH2	9.4	4.4	0.8	3.3	0.9	0.1	0.8	0.2	0.0	0.1	0.0	0.0
NANTF	*	*	*	*	*	*	*	*	*	*	*	*
MATTF	0.0	0.0	0.0	14.6	7.3	7.6	18.5	11.3	8.7	55.8	32.0	5.5

grasses from 1978–2000 at five-year intervals.

Bay Segment	1978–1984			1985–1990			1991–1995			1996–2000		
	0–0.5 m	0.5–1 m	1–2 m	0–0.5 m	0.5–1 m	1–2 m	0–0.5 m	0.5–1 m	1–2 m	0–0.5 m	0.5–1 m	1–2 m
LCHMH	6.4	0.7	0.1	19.3	4.4	0.6	9.0	2.5	0.5	37.5	16.9	2.7
PAXMH	2.0	0.4	0.1	3.7	3.1	0.8	0.1	0.0	0.0	0.3	0.1	0.0
NANO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
POTO	20.2	5.1	0.2	46.0	23.7	11.8	51.3	31.6	13.1	66.3	45.5	15.0
POTMH	2.9	0.6	0.0	2.5	0.7	0.2	4.4	1.2	0.1	15.7	5.2	0.6
HNGMH	6.9	0.9	0.0	47.8	13.6	1.2	61.2	18.8	1.2	46.2	14.3	1.4
FSBMH	0.0	0.0	0.0	1.1	0.1	0.0	2.5	0.7	0.1	0.2	0.0	0.0
CB5MH	15.8	8.4	1.2	23.1	15.9	3.5	24.4	21.3	5.1	18.8	18.7	4.0
NANMH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WICMH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RPPTF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.4	0.1
TANMH	33.2	23.2	5.3	47.3	32.8	8.7	50.0	34.0	8.9	40.0	26.1	6.6
POCTF	*	*	*	*	*	*	*	*	*	*	*	*
MANMH	3.9	1.4	0.0	11.8	3.9	0.1	10.6	5.1	0.2	11.1	2.9	0.1
RPPOH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BIGMH	13.3	13.7	0.3	24.6	11.6	0.7	21.2	8.6	0.2	24.2	11.3	0.3
POCOH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RPPMH	0.5	0.2	0.1	6.5	2.3	0.2	2.3	0.8	0.2	1.2	0.3	0.2
POCMH	11.7	12.4	0.7	17.7	17.5	3.9	19.7	17.8	2.9	17.7	16.8	2.4
CB7PH	33.1	26.1	10.8	38.2	27.6	11.0	43.7	31.0	13.6	42.1	29.0	13.9
MPNTF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.4	2.5	1.0
CRRMH	0.2	0.2	0.1	29.7	16.0	2.9	25.7	13.1	3.2	17.6	6.6	1.8
CB6PH	22.2	25.7	4.8	23.3	25.3	3.6	30.7	31.4	4.9	25.5	25.3	4.0
PMKTF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.1	8.9	2.0
MPNOH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PMKOH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PIAMH	2.5	1.2	0.7	11.7	7.4	2.5	17.3	15.2	7.2	9.8	7.8	2.5
YRKMH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
JMSTF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.5	0.5
MOBPH	36.3	37.4	5.8	41.2	44.0	8.9	44.5	49.7	8.3	45.1	48.6	8.2
CHKOH	2.9	3.7	0.8	0.6	1.9	0.3	0.0	0.0	0.0	14.8	27.6	3.5
APPTF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
YRKPH	12.1	6.7	1.0	13.9	13.7	2.5	15.8	15.3	2.7	18.3	16.2	3.2
JMSOH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
JMSMH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CB8PH	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.3	0.4	2.2	1.4	0.4
JMSPH	1.6	1.0	0.0	1.1	0.0	0.0	3.4	0.7	0.0	17.2	10.1	0.8
LYNPH	2.3	3.0	1.7	4.1	4.9	2.7	3.6	2.6	1.6	3.5	3.3	1.1
ELIPH	*	*	*	*	*	*	*	*	*	*	*	*
LAFMH	*	*	*	*	*	*	*	*	*	*	*	*
ELIMH	*	*	*	*	*	*	*	*	*	*	*	*
WBEMH	*	*	*	*	*	*	*	*	*	*	*	*

Exhibit 4-27: Percent of potential shallow-water habitat covered by underwater bay grasses from 1978–2000 at five-year intervals.

Bay Segment	1978–1984			1985–1990			1991–1995			1996–2000		
	0–0.5 m	0.5–1 m	1–2 m	0–0.5 m	0.5–1 m	1–2 m	0–0.5 m	0.5–1 m	1–2 m	0–0.5 m	0.5–1 m	1–2 m
EBEMH	*	*	*	*	*	*	*	*	*	*	*	*
SBEMH	*	*	*	*	*	*	*	*	*	*	*	*

* denotes no data available or no bay grasses mapped.

Orange – bay grasses cover ≥ 10 percent of potential habitat for all 4 time periods.

Green – bay grasses are cover ≥ 10 percent potential habitat for 3 of the time periods.

Note: While some periods span more than 5 years, each period represents only 5 years worth of data.

There were some years when no bay grasses surveys occurred (e.g., 1988).

Decision Rules

Based on these multi-decadal data (1930s through 2000), the Chesapeake Bay Program segment specific water column depth out to which the shallow-water bay grass designated use should apply and, therefore, the depth at which the water clarity criteria would apply, were determined as follows:

- In all Chesapeake Bay Program segments, the 0–0.5 meter depth interval will be minimum depth designated for the shallow-water bay grass use, except for the delineated bay grass no grow zones where no shallow-water use applies.
- In addition, the shallow-water bay grass use will be designated for deeper depths within a segment if either:
 - The single best year bay grass distribution covered at least 20 percent of the potential habitat in a deeper segment-depth interval; or
 - The single best year bay grass distribution covered at least 10 percent of the potential habitat in the segment-depth interval in at least three of the four five-year survey intervals of the 1978–2000 data record.

Focusing on the single best year versus a composite bay grasses coverage ensures that vegetated portions of potential bay grass habitats are not over accounted for based on bay grass beds that may have “migrated” year to year over two decades. Using the percent of potential habitat vegetated normalizes for variance in available habitat among segments. Applying a relatively high first cut on the percentage of potential habitat vegetation, i.e., 20 percent, provides a reasonable threshold of importance of a segment-depth interval as maximum depth of actual (past or present) bay grass habitat. Having the lower backup threshold, i.e., 10 percent, that fully utilizes the two decade record of bay grasses distributions to assess the persistence of bay grasses in a segment-depth, provides a reasonable basis for capturing those segment-depths where bay grasses were not as widely prevalent, but is relatively persistent over the past twenty years. Requiring that either the 20 percent decision rule or the greater than 10 percent plus evidence of persistent growth decision rule be met protects against over-use of “fluke” years of, say, 15 percent bay grasses coverage that never recurred in the two-decade data record.

During the process for setting the new bay grass distribution restoration goal, as committed to in the *Chesapeake 2000* agreement (Chesapeake Executive Council, 2000), the eligible segments and depths for inclusion in the calculation of the new goal were strictly limited to those segment-depth intervals which were designated for shallow-water bay grass use. The new bay grass acreage goal was derived as a fraction of the total available habitat summed over all the segment-depths that are designated for shallow water bay grass use.

Results of applying the decision rule are shown in **Exhibit 4-28** which shows the recommended shallow-water bay grass designated use outer boundary depth for all related segments.

Basis for the Percentage Cut-Offs

Underwater bay grass beds in tidal waters of Chesapeake Bay display a spatial heterogeneity that is characteristic of underwater grass beds elsewhere in the world (Lehmann et al., 1997; Kuenen and Debrot, 1995; Carpenter and Titus, 1984). This heterogeneity exists both in micro and macro scales, and as viewed by aerial photography results in a spatial distribution that is virtually never 100 percent coverage of available shallow water habitat at any depth. This was true historically as well. Manning (1957) estimated that lower Patuxent River bay grass beds covered only about one third of shoal waters. Photography from Maryland from 1938 and 1952 revealed an average percent cover of 35 percent (Naylor, 2002) at depths of less than one meter. Virginia photographic analysis revealed up to 48 percent coverage in the York and Rappahannock Rivers at less than 1 meter depth (Moore et al., 2001). These findings were supported by similar findings from analysis of the more recent 1978-2000 Chesapeake Bay bay grasses aerial survey distribution data. These data show that bay grass beds almost never occupy 100 percent of their available habitat even in the most shallow depths where light levels were high enough to support plant growth.

There are several possible reasons for less than complete habitat occupation. These include small-scale sediment type differences, small scale sediment movement patterns, sediment slope, fetch, uneven seed distribution, localized disturbance, etc. On top of these reasons for real variations in plant presence, only the most dense areas of underwater bay grasses are visible in high-altitude photography. Very sparse beds reveal no signature in the water, and are never delineated through photo interpretation. Each year, researchers find dozens of bay grass beds in places not identified in the annual survey due to these limitations. This results in reporting percent coverage that is lower than the total amount of habitat actually occupied by sparse plant beds further lowering the total percent coverage.

In addition to the natural spatial heterogeneity, the fact is that even to achieve bay grass coverage of 1 percent, light must have been available at a given depth for even a single plant to grow. Although a low percentage might imply marginal light availability, it nonetheless shows definitively that adequate light was available and, as such, should be considered suitable for setting application depths.

Maximum Depth at Which SAV Water Clarity Criteria Apply

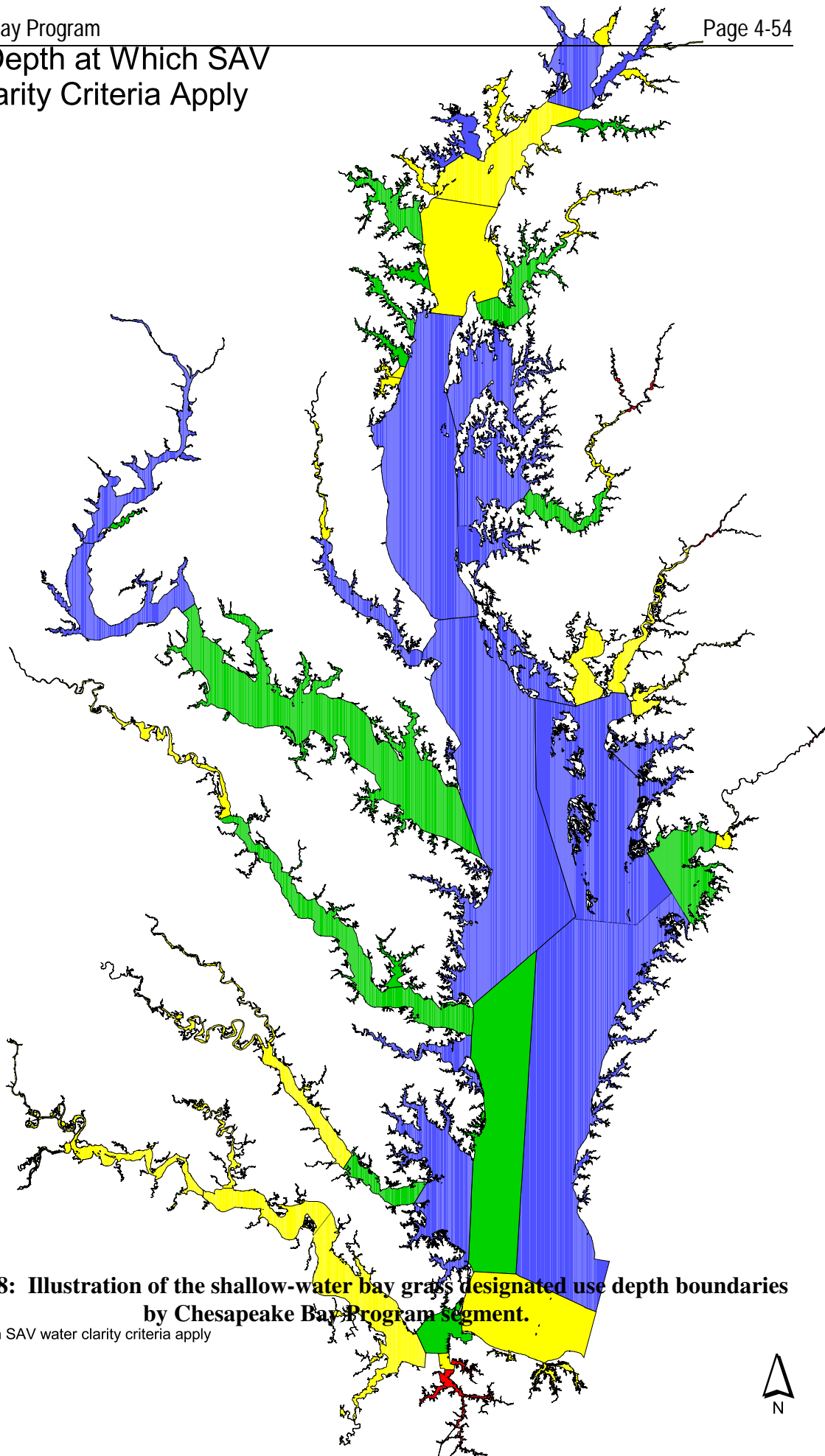


Exhibit 4-28: Illustration of the shallow-water bay grass designated use depth boundaries by Chesapeake Bay Program segment.

Maximum depth at which SAV water clarity criteria apply

- 0-0.5m
- 0.5-1m
- 1-2m
- No-grow area

For setting application depths, it was important to select a percentage of cover high enough to assure that plants definitely occupied that habitat, but low enough that attainment depths realistically represented true light availability in the past. Given the starting point of 1 percent, and the typical maximum of 35–48 percent from the historical photography, 20 percent was seen as a reasonable, defensible midpoint reflective of sufficient coverage to define maximum depth of the bay grasses growth.

Depth Boundaries

The shallow-water bay grass designated use outer boundary depths are illustrated in **Exhibit 4-29**. Exhibit 4-26 documents the single best year, the shallow-water bay grass designated use depth boundary and which decision rule was used to set the depth for each Chesapeake Bay Program segment.

Nine Chesapeake Bay Program segments were not assigned a shallow-water bay grass designated use depth boundary (Exhibit 4-26). The established bay grass no-grow zones covered the 2-meters and less habitats along the entire tidal shoreline in each of these segments—upper Choptank River, upper Nanticoke River, upper Pocomoke River, Western Branch Elizabeth River, Southern Branch Elizabeth River, Eastern Branch Elizabeth River, Middle Elizabeth River, Lafayette River and mouth of the Elizabeth River (Appendix C).

4.4 CONFIRMING THE REFINED DESIGNATED USES MEET EXISTING USES

The EPA Water Quality Standards regulations at 40 CFR 131.10(g) and (j) specify that States may remove a designated use that is not an existing use, or establish subcategories of a use, if they can demonstrate that attaining the designated use is infeasible. The current regulation at 40 CFR Part 131 identifies the factors that must be considered in making such a demonstration. As explained in the regulation, existing uses, by definition, are attainable and must be protected by designated uses in water quality standards (40 CFR 131.10(g), 131.10(h)(1) and 131.10(i)). Any change in designated uses must show that the existing uses are still being protected. As described in the EPA 1983 Water Quality Standards Handbook, an existing use can be defined as fishing, swimming or other uses that have actually occurred since November 28, 1975; or the water quality that is suitable to allow the use to be attained—unless there are physical problems, such as substrate or flow, that prevent the use from being attained.

Section 131.12(a)(1) in turn requires State anti-degradation policies to protect existing water quality. This paragraph applies a minimum level of protection to all waters.

In setting the new shallow-water use and four subcategories of current designated uses, explicit steps were taken in the development of the refined uses and their boundaries to ensure existing aquatic life uses would continue to be protected.

Shallow Water Designated Use

- 0.5 meter
- 1 meter
- 2 meter

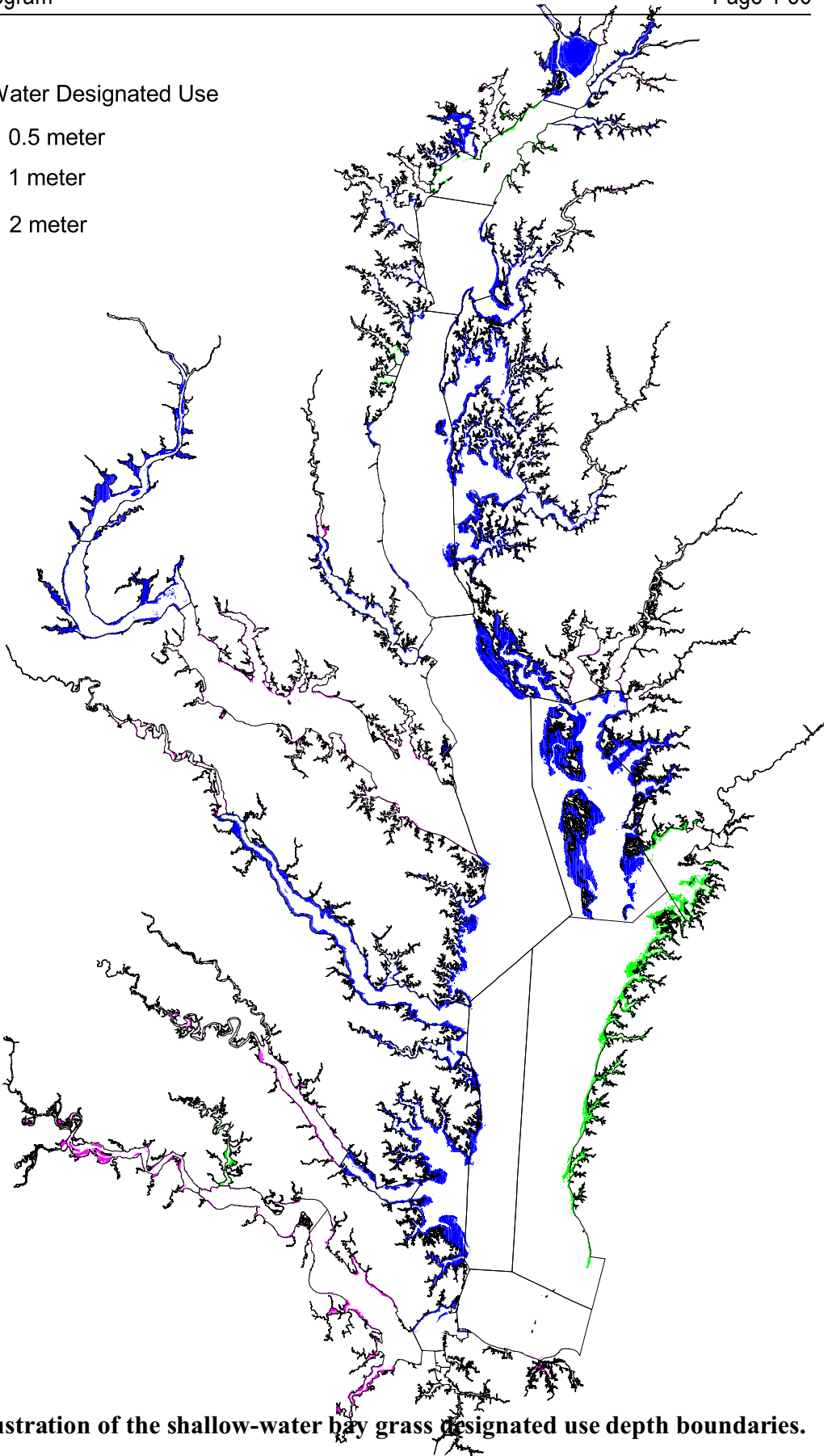


Exhibit 4-29: Illustration of the shallow-water bay grass designated use depth boundaries.

The **shallow-water bay grass designated use** is being proposed as a new designated use for tidal Chesapeake Bay waters. In delineation of the shallow-water use, the single best year of underwater grasses distribution mapped since the 1930s was used to define the depth-based boundary for each respective Chesapeake Bay Program segment. As a majority of the single-best years were based on historical bay grasses distributions (1930s through the early 1970s), the bay grass-related uses existing since 1975 will continue to be protected.

The **migratory fish spawning and nursery designated use** will be protected by a set of DO criteria that are more protective—6 mg liter⁻¹ 7 day mean and 5 mg liter⁻¹ instantaneous minimum—than current State water quality standards that apply to these same habitats during February 1 through May 31 (U.S. EPA, 2003). Existing uses within the migratory spawning and nursery habitats will continue to be protected.

The **open-water fish and shellfish designated use** DO criteria will provide an equal level of protection as the current State water quality standards which apply to these same tidal waters. The combined set of 5 mg liter⁻¹ 30 day mean, 4 mg liter⁻¹ 7 day mean, and 3 mg liter⁻¹ instantaneous minimum have shown to fully protect an array of open-water habitats species in Chesapeake Bay and its tidal waters (U.S. EPA, 2003). Existing uses within the open-water habitats will continue to be protected.

The application of **deep-water seasonal fish and shellfish designated use** and **deep-channel seasonal refuge designated use** and their respective protective DO criteria will result in improvements to existing water quality conditions which currently don't attain the applicable criteria (see Section 5). The boundaries for both uses were derived, in part, on the best DO conditions documented in the past two decades. Given trends in DO conditions have been generally degrading (see Section 3) since the early 1970s, improvements to these conditions will ensure existing uses within the deep-water and deep-channel habitats will continue to be protected.